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AN ASSESSMENT OF ROOT DISEASES IN THE ROCKY MOUNTAIN REGION

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ABSTRACT

Investigations of root disease losses in the Rocky Mountain Region are in their infancy; however, three root disease organisms have been identified as posing a concern to forest resource managers. They are *Armillaria mellea, Fomes annosus* and *Ceratocystis wageneri*. Current known distribution, hosts, importance, field identification, and implications in future management are discussed separately for each of these pathogens.

INTRODUCTION

Root diseases are one of the most damaging classes of forest tree diseases in the western United States. These root diseases cause economic loss by killing trees, slowing growth, decaying wood, predisposing trees to other harmful pests, causing trees to fail and fall over, preventing reforestation, and reducing stocking levels on regeneration sites.

In a recent assessment of root disease-caused losses for the western United States, Smith (1984) estimated average annual volume loss in commercial forest lands at 237.4 million cubic feet. This loss is approximately 18 percent of the total softwood mortality reported for the West.

Investigations of root disease losses in the Rocky Mountain Region are in their infancy; therefore, no data are available on volume loss. Although study plots have been established throughout the Region to monitor disease development in various host types (Table 1-Appendix), no loss estimates have been generated from this data.

GENERAL DISCUSSION OF ROOT DISEASES, HOSTS AND IMPORTANCE

Surveys of root diseases conducted throughout the Region have identified three major root disease organisms: *Armillaria mellea, Fomes annosus* and *Ceratocystis wageneri*. Each of these pathogens will be discussed separately.

1. Shoestring Root Disease

Shoestring root disease, caused by *Armillaria mellea,* is the most common and widely distributed root disease in the Region. Tree species susceptibility varies by host species, vigor, age, and habitat type. The fungus is commonly observed on lodgepole pine (*Pinus contorta*), ponderosa pine (*P. ponderosa*) and subalpine fir (*Abies lasiocarpa*). The fungus has also been recorded on pinyon (*P. edulis*), Engelmann spruce (*Picea engelmannii*), white fir (*Abies concolor*), aspen (*Populus tremuloides*), Rocky Mountain juniper (*Juniperus scopulorum*), and cottonwoods (*Populus* spp.).

Armillaria mellea commonly lives as a saprophyte on dead organic material such as old stumps left from logging. From stumps it can spread to living hosts by root contacts and rhizomorphs, which are red-brown or black cords of fungus mycelium similar to shoestrings (1-5 mm in diameter). Rhizomorphs can grow through the soil from the food base to the roots of living trees. The fungus spreads from the roots to the root collar and can parasitize and girdle the tree. In late summer during wet periods the fungus produces mushrooms which are found in clumps near the base of infected trees or stumps. The mushroom cap is honey-colored

with dark fibril-like scales underneath, and the stalk has a ring around its base. Spores released from the mushrooms infect butt and root wounds.

This root disease is relatively easy to identify. The signs and symptoms to look for are:

(a) declining growth (especially height), yellowing foliage, stress crop of cones, small trees often dying in groups (typical of all root diseases) (Plate 1A.)

(b) resin exudate on the trunk near the soil line and mixed with soil at the root collar (Plate 1B.)

(c) thick, white mycelial fans under the bark of roots and around the root collar (Plate 1B.)

(d) presence of rhizomorphs (underground or under the bark of roots) or mushrooms (Plate 1C.)

Armillaria mellea occurs commonly in association with bark beetle and woodborer attacked and killed trees. The following insects have been noted in *A. mellea* infected trees: *Dendroctonus ponderosae, D. valens, Dryocoetes confusus, Ips* spp., *Scolytus ventralis,* Buprestidae and Cerambycidae. A study conducted in the Colorado Front Range showed that 62% of mountain pine beetle, *D. ponderosae,* killed ponderosa pine were also infected by *A. mellea* (Fuller, 1983).

In a recent unpublished study of 63 stands of ponderosa pine, of various age and size classes in the Black Hills of South Dakota, 89% of these stands had *A. mellea* infected trees and 71% had both *A. mellea* and mountain pine beetle present. In another unpublished study in the Black Hills, 75% of mountain pine beetle infested and killed trees had *A. mellea* present indicating a strong preference for the beetle to attack *A. mellea* stressed trees.

Armillaria is also common in cutover lodgepole pine stands that have regenerated naturally. An evaluation of a 31 year old stand showed that 12% of the culmulative mortality was attributed to *A. mellea* (Johnson and Hawksworth, 1977). No disease centers were large enough to result in understocking of the stand. Annual loss of trees over a period of 18 years of observations showed a reduction in tree mortality from nearly 2% per annum to less than 0.5%.

Surveys of naturally regenerated seedling-sapling stands indicate up to 11% of trees infected or killed by *A. mellea.* Disease incidence is not uniform throughout stands. Most diseased trees are located near stumps, which probably served as inoculum sources.

Armillaria also is common in mortality centers of pinyon east of the Continental Divide in Colorado (Fig. 1). In surveys of diseased wood-

Plate 1. Shoestring Root Disease

A. Group of dying and dead lodgepole pine regeneration caused by *Armillaria mellea*.

B. Mycelial fans and resin mixed with soil at the base of an infected lodgepole pine.

C. Groups of mushrooms fruiting at the base of an infected true fir.


A


B


C

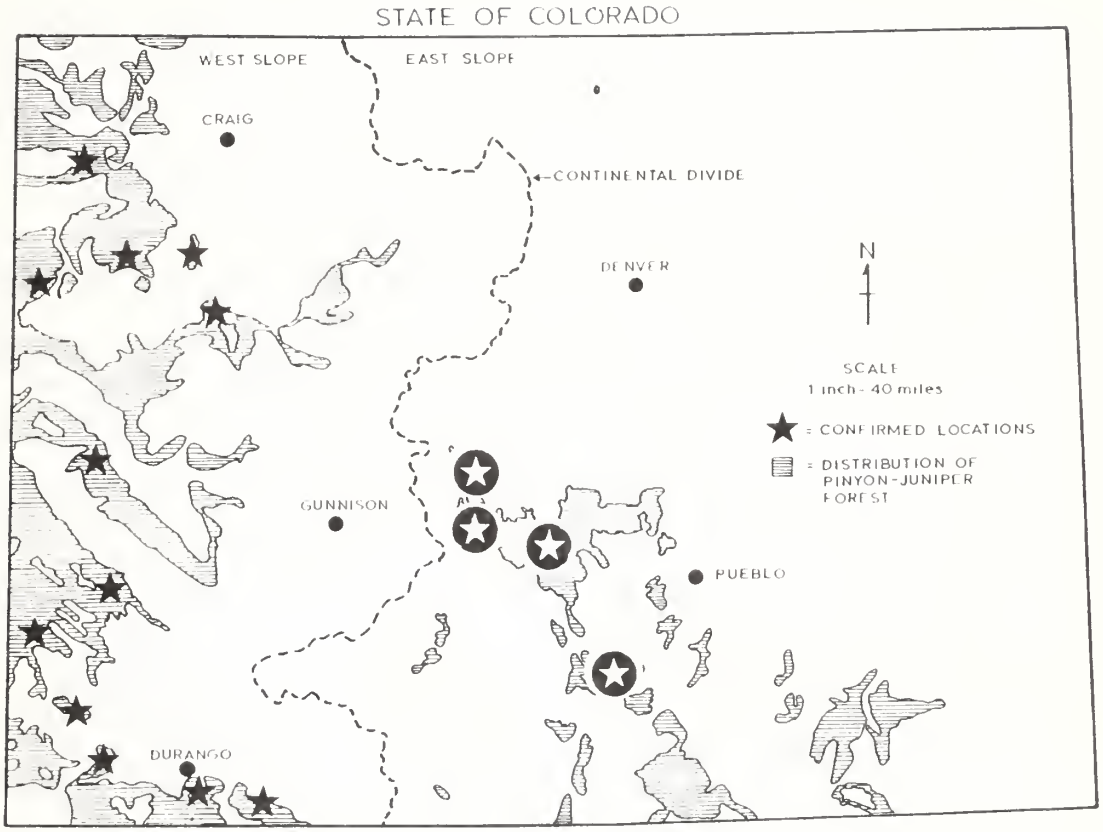


Figure 1. General locations of Armillaria root disease ★ and black stain root disease ★ in the pinyon-juniper type in Colorado.

lands (Johnson et al, 1976), up to 21% of pinyon were infected or killed by *A. mellea* (up to 41 infected trees per acre).

2. Annosus Root Disease

Annosus root disease, caused by *Fomes annosus*, was first reported in 1931 in this Region on Engelmann spruce during a mycological survey (Shope 1931). In 1965 it was reported on jack pine (*Pinus banksiana*) in plantations established in 1911 as part of the Nebraska National Forest (Stewart, 1965). Other hosts identified include eastern red-cedar (*Juniperus virginiana*). Only recently has the fungus been identified as causing mortality of native white fir and subalpine fir in southern Colorado (Fig. 2) (James and Goheen, 1980 and 1981).

Fomes annosus is most important on white fir in this Region. It causes white, stringy, root and butt decay of trees of all age classes. Mortality occurs in groups (infection centers) (Plate 2A). The fungus produces airborne basidiospores which infect surfaces of freshly-cut stumps and trunk wounds. There has been some indication of direct root infection by spores. The fungus colonizes infected trees or stumps and spreads to adjacent trees via root contacts. Sporophores, which produce basidiospores, are found within infected stumps and dead trees (common) (Plate 2B) or at the base of infected trees under the litter layer (uncommon) (Plate 2C). The fungus has been found in uncut stands; however, mortality is more extensive in stands that have been partially cut.

Observations of the fungus in pines indicates that root disease centers may be active for at least 30 to 40 years. However, we have no knowledge of persistence of the fungus in fir stumps and root systems. The fungus can act as a saprophyte in dead root systems and persist until the wood is completely decayed.

Groups of dead and dying white fir, especially near stumps, are a good indication of this disease. Infected trees often have heavy resin accumulation at their root collar. Presence of the fungus can be confirmed by locating sporophores.

The fungus is often found with other decay fungi in white fir, including *A. mellea* and *Echinodontium tinctorium*. The fir engraver, *Scolytus ventralis*, is also associated with *F. annosus* infected trees.

Mortality occurs as single trees or groups of trees up to an acre. Root and butt rot can be extensive and predispose infected trees to wind-breakage and windthrow. The disease is often associated with stumps created by partial cutting; however, it also occurs in uncut stands where natural wounds may have provided infection courts. During a survey of mortality of true fir species in southern Colorado, it was found that 59% of symptomatic white fir were infected by *F. annosus;* 3% of subalpine fir were infected (James and Goheen, 1981).

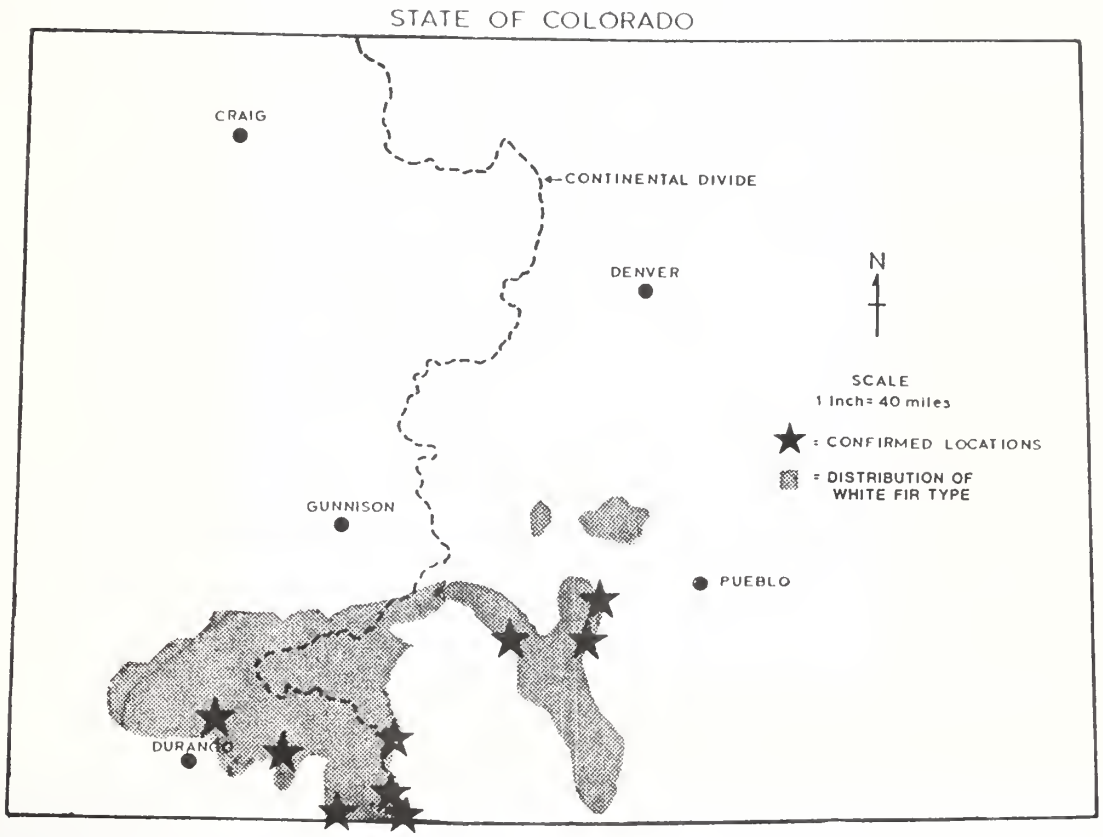


Figure 2. Locations of concentrations of annosus root disease centers in the white fir type in Colorado.

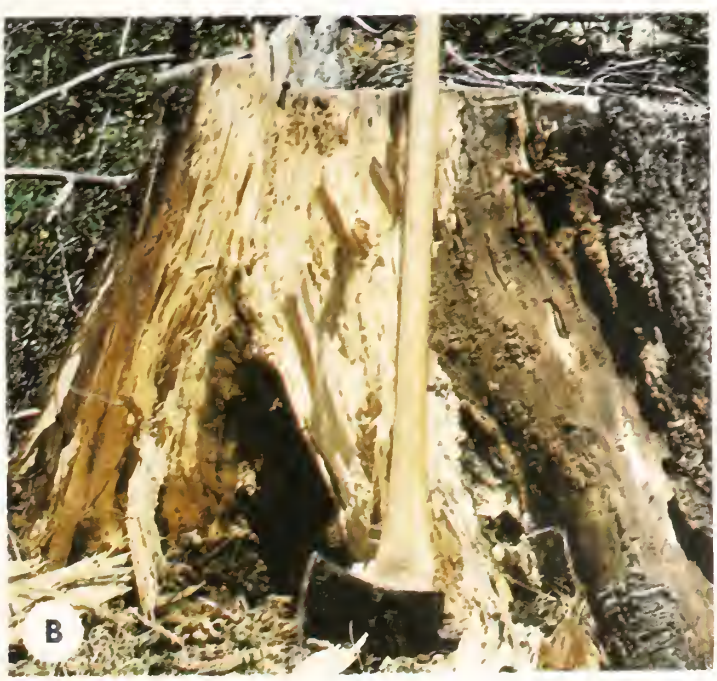
Plate 2. Annosus Root Disease

A. *Fomes annosus* infection center in subalpine fir. Note stumps in center of photo.

B. Old infected stumps often harbor sporophores.

C. Sporophores fruiting on roots of an infected tree.


A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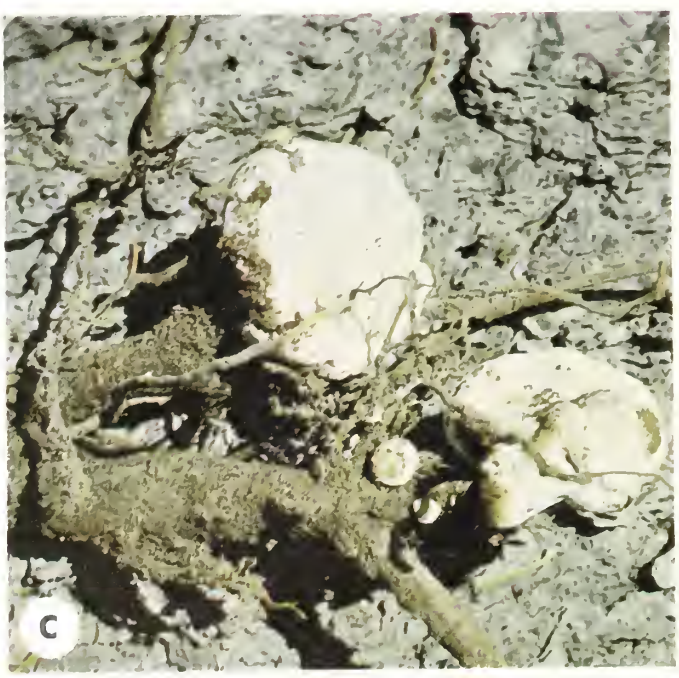
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3. Black Stain Root Disease

Black stain root disease, caused by *Ceratocystis (Verticicladiella) wageneri*, was first discovered in 1942 in Colorado on pinyon in Mesa Verde National Park.

Aerial and ground surveys conducted since 1975 have shown the disease to be widespread in the Park and throughout the pinyon-juniper woodlands west of the Continental Divide in Colorado (Fig. 1) (Landis and Helburg 1976; James and Lister, 1978). The disease has also been reported twice on Douglas-fir east of the Continental Divide.

The fungus infects the root system and lower bole of the tree and restricts water conduction. Infected trees gradually decline in vigor with death ultimately occurring after several years. The disease spreads through root contacts and grafts causing pockets of dying and dead trees up to one acre in size (Plate 3A). Long range spread is believed to result from insect transmission of the fungus by the pine engraver, *Ips confusus*.

Ceratocystis wageneri does not decay wood but rather dies out in infected root systems a few years after the host tree dies. In some circumstances it is possible to control the disease by cutting all susceptible trees in a 75 foot wide zone beyond the visible boundaries of an infection center. The control area can be immediately replanted with non-susceptible species such as Rocky Mountain juniper, Douglas-fir and ponderosa pine.

Diseased pinyon can be identified by the sparse, chlorotic foliage and the characteristic black stained sapwood at the base of the tree (Plate 3B) or in the roots. The pocket nature of the disease is also characteristic with older dead trees in the center and more recently infected individuals around the perimeter. This disease can be distinguished from typical blue stain associated with insect activity by the pattern of growth of the mycelium in the sapwood. On cross-section *C. wageneri* appears as concentric zones while blue stain appears as wedge (pie) shapes (Plate 3C, D).

All ages and sizes of pinyon are susceptible. The disease appears to be restricted to cool, moist sites with deep soils and greater tree density.

Spread of the disease within pinyon mortality centers appears to be selflimiting over time as revealed by examination of plots established in 1944 and revisited. Regeneration has occurred within these centers and no recent mortality to *C. wageneri* has been recorded (James and Lister, 1978). The reasons for stabilization of tree mortality within disease centers after a few years is not known; however, some evidence suggested that infected root systems are usually invaded by secondary fungi which may replace *C. wageneri*. Additional plots have been established in mortality centers to follow progress of the disease over time and to answer some of these questions (Table 1 - Appendix).

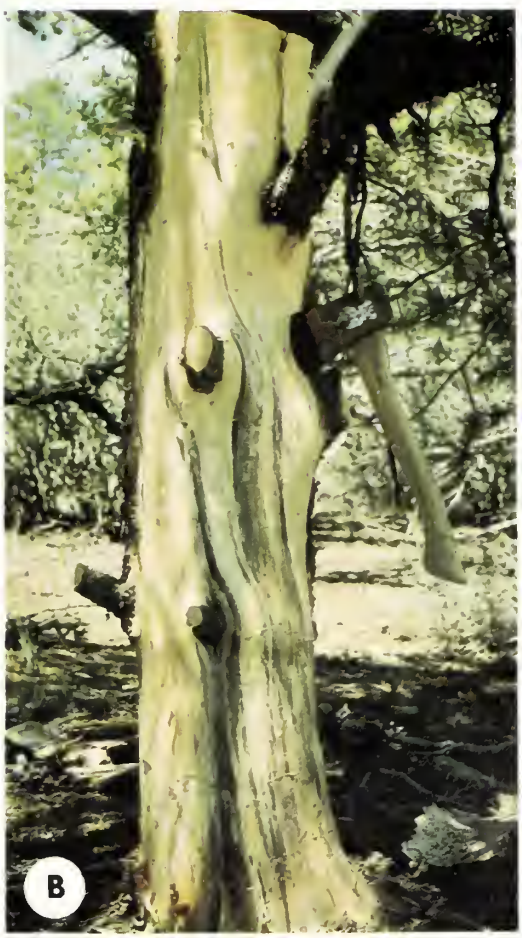
Plate 3. Black Stain Root Disease

A. *Ceratocystis wageneri* disease center in pinyon. Note older dead trees in the center and live trees at the edge.

B. Black stained sapwood at the base of an infected pinyon.

C. Cross-section of *C. wageneri* infected tree. Note concentric pattern of stain (C) versus wedge-shaped pattern (D) for blue stain (also a species of *Ceratocytis*).


A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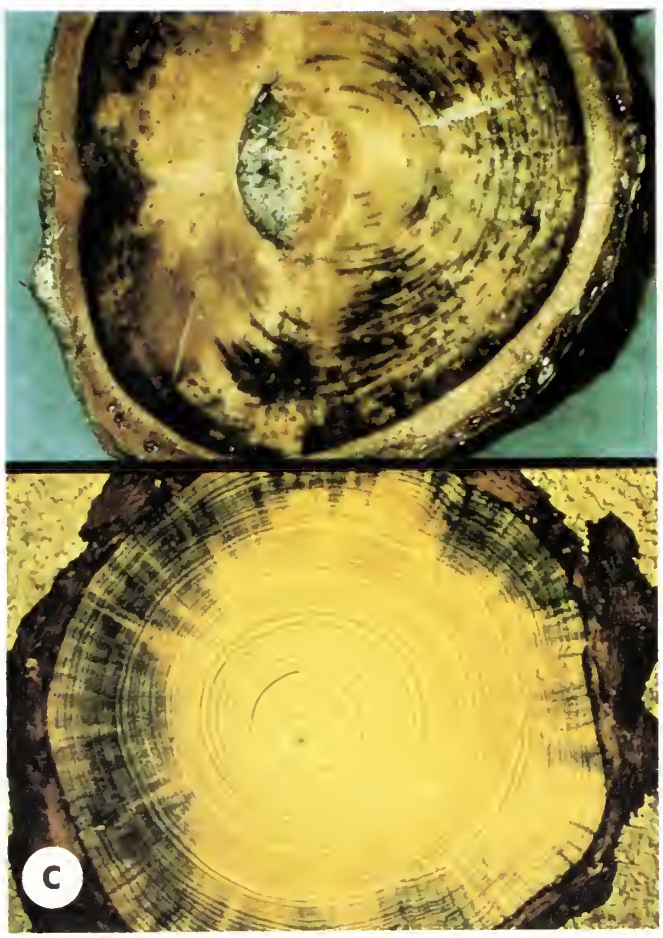
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MANAGEMENT IMPLICATIONS

Each of the root diseases will be treated separately since the host range and knowledge of each pathogen varies greatly.

1. Shoestring Root Disease

At this stage in development of our knowledge of *A. mellea*, it is not possible to determine the implications of the disease on timber management practices or other resources. The disease is widespread throughout the Rocky Mountain Region and has been reported on all coniferous species and some hardwoods. It causes scattered tree mortality and predisposes its host to bark beetle attack and windthrow. It also causes decay in live trees. The disease may pose problems in the future as stands are placed under more intensive management. On the other hand, activities that increase the vigor of the residual stand may reduce losses to the disease.

In some young stands, reduction of stocking levels through accumulated mortality may pose a management concern. The effects of thinning infected stands are unknown at this time.

Recognition and removal of root disease infected trees in developed recreation sites is a management concern. Training has been provided to the Forests to aid in reduction of this hazard (Sharon and Steinke, 1982). A survey was conducted throughout the Region in 1982-83 in all forest types to determine the hazard in campgrounds. A report will be issued in 1984. Other adverse effects of root diseases include buildup of woody fuels and creation of brood material for bark beetles and subsequent loss of adjacent trees as bark beetle populations increase.

Beneficial effects of root diseases include the creation of natural openings and wildlife habitat and increased diversity of plant species as regeneration of root disease centers occurs.

2. Annosus Root Disease

The effects of *Fomes annosus* on the forest resource are even less known than for *A. mellea*. The disease has been only recently recognized as a potential threat to productivity of true fir stands in the Region (James, 1979; James and Gillman, 1979). It is expected that the disease will become more of a management concern as thinning and partial cutting of spruce-fir stands increase (Hinds et al, 1983).

Recently, DeNitto (1984) presented some management guidelines for *F. annosus* infected true fir stands. These included avoiding damage to the cambium from logging and prescribed fire, reducing the number of stand entries for thinning and harvest activities, shortening rotation ages, promoting mixed species stands, regenerating to less susceptible tree species, treating stumps with borax, and stump removal.

In the southeastern United States thinning of susceptible pine stands is restricted to the hottest months of the year and borax is applied to freshly cut stump surfaces. These disease preventative techniques have not been tested in the Rocky Mountain Region.

3. Black Stain Root Disease

Black stain root disease has attracted the attention of recreation management specialists in the past few years. Concern for tree loss in urban areas and in several developed recreation sites, including Mesa Verde National Park, has stimulated evaluations of the disease. Silvicultural, mechanical and chemical techniques are currently being evaluated for effectiveness in reducing spread of disease centers.

The disease also causes increased fuel loading as deterioration rates of dead trees are very slow in these arid to semi-arid sites.

Additional tree loss occurs as pine engraver, *Ips confusus*, populations increase in disease centers and attack adjacent trees.

CONCLUSION

At the present state of our knowledge of root diseases in the Rocky Mountain Region, it is not possible to predict current losses in productivity of infected stands or estimate future losses as stands are more intensely managed. Site specific rehabilitation treatments cannot be justified at the current level of harvest activity as can be for the Pacific Northwest or Southeast. Stand treatments may be warranted in the future if root disease-caused losses adversely imapct management plans for those sites.

The Forest Pest Management Staff should be consulted when site specific recommendations are needed. A biological evaluation and management strategy can be developed for potential problem areas.

REFERENCES

1. DeNitto, G. 1984. Guidelines for reducing the effects of *Fome annosus* in true fir in stands managed for timber. USDA For. Serv., Forest Pest Management, Pacific Southwest Region, Report 84-21, 6 pp.

2. Fuller, L. R. 1983. Incidence of root diseases and dwarf mistletoe in mountain pine beetle killed ponderosa pine in the Colorado Front Range. USDA For. Serv., Forest Pest Management, Rocky Mountain Region, Bio. Eval. R2-83-2, 8 pp.

3. Hinds, T. E., R. E. Wood and R. L. Bassett. 1983. Wounds and decay in residual corkbark fir. USDA For. Serv., Rocky Mountain For. and Range Exp. Sta. Res. Paper RM-247, 6 pp.

4. James, R. L. 1979. *Fomes annosus* on white fir in Colorado. Plant Dis. Reptr. 63:129-130.

5. James, R. L. and L. S. Gillman. 1979. *Fomes annosus* on white fir in Colorado. USDA For. Serv., Forest Insect and Disease Management, Rocky Mountain Region Tech. Report R2-17, 9 pp.

6. James R. L. and L. S. Gillman. 1980. Root disease surveys of selected managed conifer stands on the Routt, Gunnison, and White River National Forests in Colorado. USDA For. Serv., Forest Insect and Disease Management, Rocky Mountain Region. Bio. Eval. R2-80-2, 21 pp.

7. James, R. L. and D. J. Goheen. 1980. Distribution and characteristics of conifer root diseases on the San Isabel, Rio Grande, San Juan, and Grand Mesa National Forests in Colorado. USDA For. Serv., Forest Insect and Disease Management, Rocky Mountain Region. Bio. Eval. R2-80-4, 17 pp.

8. James, R. L. and D. J. Goheen. 1981. Conifer mortality associated with root disease and insects in Colorado. Plant Dis. 65:506-507.

9. James, R. L. and C. K. Lister. 1978. Insect and disease conditions of pinyon pine and Utah juniper in Mesa Verde National Park, Colorado. USDA For. Serv., Forest Insect and Disease Management, Rocky Mountain Region, Bio. Eval. R2-78-4, 16 pp.

10. Johnson, D. W. and F. G. Hawksworth. 1977. Shoestring root rot in a lodgepole pine stand, Poudre Ranger District, Arapaho and Roosevelt National Forest. USDA For. Serv., Forest Insect and Disease Management, Rocky Mountain Region, Bio. Eval. R2-77-22, 4 pp.

11. Johnson, D. W., T. D. Landis, and L. S. Gillman. 1976. Shoestring root rot of pinyon-juniper stands, San Isabel National Forest, BLM, State and Private Lands. USDA For. Serv., Forest Insect and Disease Management, Rocky Mountain Region, Bio. Eval. R2-76-14, 4 pp.

12. Johnson, D. W., T. D. Landis, and L. S. Gillman. 1976. Rocky Mountain juniper, a new host of *Armillariella mellea* in Colorado. Plant Dis. Reptr. 60:886.

13. Landis, R. D. and L. B. Helburg. 1976. Black stain root disease of pinyon pine in Colorado. Plant Dis. Reptr. 60:713-717.

14. Sharon, E. M. and D. Steinke. 1982. How to evaluate hazard trees in recreation sites. R-2 Slide/Tape Instructor Training Package. (Three carousel trays of slides plus text). Available on loan from the Forest Pest Management Staff Unit, R-2.

15. Shope, P. K. 1931. The Polyporaceae of Colorado. Ann. Mo. Bot. Gard. 18:287-456.

16. Smith, R. S. Jr. 1984. Root disease-caused losses in the commercial coniferous forests of the western United States. USDA For. Serv., Forest Pest Management, Methods Application Group, Ft. Collins, CO. Rep. No. 84-5, 21 pp.

16. Stewart, J. L. 1965. *Fomes annosus* found in Nebraska. Plant Dis. Reptr. 49(5):456.

APPENDIX

Table 1. Root disease evaluation plots in Colorado monitored by Forest Pest Management.

Forest	Ranger District	Plot identification	Tree species present [1/]	Root diseases present [2/]	Year plot established
Gunnison	Cebolla	Canyon Creek #1	LPP	*A.m.*	1978
		Canyon Creek #2	LPP	*A.m.*	1978
		Canyon Creek #3	LPP	*A.m.*	1978
		Canyon Creek #4	LPP	*A.m.*	1978
		Canyon Creek #5	LPP	*A.m.*	1978
		Canyon Creek #6	LPP	*A.m.*	1978
		Powder House #1	LPP	*A.m.*	1978
		Powder House #2	LPP	*A.m.*	1978
		Powder House #3	LPP	*A.m.*	1978
		Powder House #4	LPP	*A.m.*	1978
		Powder House #5	LPP	*A.m.*	1978
		Powder House #6	LPP	*A.m.*	1978
Roosevelt	Estes-Poudre	Buckhorn	LPP	*A.m.*	1959
Routt	Hahns Peak	Mill Creek #1	LPP, ES, A	*A.m.*	1978
		Mill Creek #2	LPP, ES, SAF	*A.m.*	1978
		Mill Creek #3	LPP, ES	*A.m.*	1978
		Mill Creek #4	LPP	*A.m.*	1978
		Mill Creek #5	LPP	*A.m.*	1978
San Juan	Dolores	Gravel Pit Cut #1	P-J	*V.w.*	1982
		Gravel Pit Cut #2	P-J	*V.w.*	1982
		Sage Hen Cut #3	P-J	*V.w.*	1982
		Sage Hen Cut #4	P-J	*V.w.*	1982
		House Creek Cut #5	P-J	*V.w.*	1982

Table 1. Root disease evaluation plots in Colorado monitored by Forest Pest Management (continued)

Forest	Ranger District	Plot identification	Tree species present [1/]	Root diseases present [2/]	Year plot established
White River	Sopris	Piney Creek #1	SAF, A	*A.m.*	1981
		Piney Creek #2	SAF, ES, A	*A.m.*	1981
		Last Chance #1	LPP	*A.m.*	1978
		Last Chance #2	LPP	*A.m.*	1978
		Last Chance #3	LPP	*A.m.*	1978
		Last Chance #4	LPP	*A.m.*	1978
Mesa Verde National Park		Tunnel #1	P-J	*V.w.*	1978
		Tunnel #2	P-J	*A.m.*	1978
		Moccasin #1	P-J	*V.w.*	1978
		Moccasin #2	P-J	*V.w.*	1978
		Wetherill #1	P-J	*V.w.*	1978
		Wetherill #2	P-J	*V.w.*	1978
		Chapin #2	P-J	*V.w.*	1978
		Mielke #1	P-J	*V.w.*	1944
Mesa Verde National Park (control plots)		Chapin Trench #1	P-J	*V.w.*	1982
		Ruins Road Trench #2	P-J	*V.w.*	1982
		Balcony House Trench #3	P-J	*V.w.*	1982
		Sewage Pond Fumigant #1	P-J	*V.w.*	1982
		Ruins Road Fumigant #2	P-J	*V.w.*	1982
		Fire Temple Fumigant #3	P-J	*V.w.*	1982

1/ Tree species: LPP = lodgepole pine; ES = Engelmann spruce; SAF = subalpine fir; A = aspen; P-J = pinyon-juniper.

2/ Root diseases: *A.m.* = *Armillaria mellea*; *V.w.* = *Verticicladiella wageneri*.